Docket No. : 02313/100F138-US2
(PATENT)

CLONING AND RECOMBINANT PRODUCTION OF *POLISTINAE* VENOM ENZYMES, SUCH AS PHOSPHOLIPASE AND HYALURONIDASE, AND IMMUNOLOGICAL THERAPIES BASED THEREON

CROSS REFERENCE TO REALTED APPLICATIONS

The present application is a divisional of application serial no. 09/806,658, which is the U.S. national phase of international application no. PCT/US99/23211, filed October 1, 1999, and which is a continuation-in-part of serial no. 09/166,205, filed October 1, 1998, now U.S. Patent No. 6,372,471.

FIELD OF THE INVENTION

The present invention is directed to nucleic acid molecules encoding *Polistinae* venom allergens, in particular enzymes such as phospholipase and hyaluronidase, or fragments thereof, recombinant vectors comprising such nucleic acid molecules, and host cells containing the recombinant vectors. The invention is further directed to expression of such nucleic acid molecules to produce a recombinant *Polistinae* venom enzyme, such as phospholipase or hyaluronidase, or recombinant fragments thereof. Such an allergen and fragments thereof are useful for diagnosis of allergy, for therapeutic treatment of allergy, for the treatment of immune system related diseases or disorders, or symptoms related thereto, and for the modulation of immune response towards an immunogen.

BACKGROUND OF THE INVENTION

Insect sting allergy to bees and vespids is of common occurrence. The vespids include hornets, yellow jackets and wasps (Golden, et al., 1989, Am. Med. Assoc. 262:240). Susceptible people can be sensitized on exposure to minute amounts of venom proteins; as little as 2-10 μg of protein is injected into the skin on a single sting by a vespid (Hoffman and Jacobson, 1984, Ann. Allergy. 52:276).

There are many species of hornets (genus *Dolichovespula*), yellow jackets (genus *Vespula*) and wasp (genus *Polistes*) in North America (Akre, et al., 1980, "Yellowjackets of America North of Mexico," Agriculture Handbook No. 552, US Department of Agriculture). The vespids have similar venom compositions (King, et al., 1978, Biochemistry 17:5165; King, et al., 1983, Mol. Immunol. 20:297; King, et al., 1984, Arch. Biochem. Biophys. 230:1; King, et al., 1985, J. Allergy and Clin. Immunol. 75:621; King, 1987, J. Allergy Clin. Immunol. 79:113; Hoffman, 1985, J. Allergy and Clin. Immunol. 75:611). Their venom each contains three major venom allergens, phospholipase (37 kD), hyaluronidase (43 kD) and antigen 5 (23 kD) of as yet unknown biologic function. U.S. Patent No. 5,593,877 describes cloning and expression of the vespid venom allergens phospholipase and hyaluronidase. As described in this patent, the recombinant allergens permit expression of a protein or fragments thereof for use in immunotherapy, dignostics, and to investigate T and B cell allergens, it sets forth in greater detail the rationale for cloning vespid venom enzymes. However, unique vespid venom cDNAs were not described.

In addition to the insect venom allergens described above, the complete amino acid sequence of several major allergens from different grass (Perez, et al., 1990, J. Biol. Chem. 265:16210; Ansari, et al., 1989, Biochemistry 26:8665; Silvanovich, et al., 1991, J. Biol. Chem. 266:1204), tree pollen (Breiteneder, 1989, EMBO J. 8:1935; Valenta, et al., 1991, Science, 253:557), weed pollen (Rafnar, et al., 1991, J. Biol. Chem. 266:1229; Griffith, et al., 1991, Int. Arch. Allergy Appl. Immunol. 96:296), mites (Chua, et al., 1988, J. Exp. Med. 167:175), cat dander (Griffith, et al., 1992, Gene. 113:263), and mold (Aruda, et al., 1990, J. Exp. Med. 172:1529; Han, et al., 1991, J. Allergy Clin. Immunol. 87:327) have been reported in the past few years. These major allergens are proteins of 10-40 kD and they have widely different biological functions. Nearly all

allergens of known sequences have a varying extent of sequence similarity with other proteins in our environment.

Although U.S. Patent No. 5,593,877 provides for cloning and expression of vespid venom enzymes, particularly hyaluronidase and phospholipase, there remains a need to identify unusual and unexpected sequences for such enzymes, and to design effective expression systems for them. There is a particular need to delineate the B and helper T cell epitopes of the paper wasp (*e.g., Polistes annularis*). In particular, the major *Polistinae* venom allergens phospholipase and hyaluronidase are appropriate targets for determining the important B and T cell epitopes. In order to fully address the basis for allergic response to vespid allergens, and to develop allergen-based immunotherapies, the cDNA and protein sequences of several homologous allergens need to be investigated. Moreover, vectors suitable for high level expression in bacteria and eukaryotic cells of vespid allergens or their fragments should be developed. Recombinant vespid allergens and their fragments may then be used to map their B and T cell epitopes in the murine and, more importantly, human systems by antibody binding and T cell proliferation tests, respectively.

There is also a need in the art to use peptides having T or B cell epitopes of vespid venom allergens to study induction of tolerance in mice and induction of tolerance in humans.

There is a further need to test whether a modified peptide inhibits allergen T cell epitope binding to MHC class II molecule, or induces T cell anergy, or both.

Thus, there is a need in the art for unique sequence information about vespid venom allergens, and a plentiful source of such allergens for immunological investigations and for immunological therapy of the allergy.

Furthermore, due to the overuse of antibiotics throughout the world, and to the spread of numerous viruses, such as HIV, Ebolla, etc., efforts have been made to produce new "super" antibiotic medication, and compounds which have activity against viruses. For example, AZT has been developed, along with protease inhibitors to treat subjects suffering from HIV. However, the costs of developing new "super" antibiotics and anti-viral medications are enormous.

Hence, what is needed are agents and pharmaceutical compositions for treating immune system related diseases or disorders whose activity is not dependent necessarily on combating the particular virus or pathogen, but rather modulate or potentiate

the immune system ability to combat the disease or disorder, thereby ameliorating the disease or disorder, or a symptom related thereto. Hymenoptera venoms, particularly vespid venoms, provide one possible source for such agents and pharmaceutical compositions, as described in U.S. Patent Nos. 4,822,608 and 5,827,829.

The citation of references herein shall not be construed as an admission that such is prior art to the present invention.

SUMMARY OF THE INVENTION

The present invention provides a nucleic acid molecule encoding *Polistinae* venom enzymes, immunomodulatory fragments thereof, or derivatives or analogs thereof. In particular, the invention is directed to such nucleic acid molecules encoding a *Polistinae* venom phospholipase, and a *Polistinae* venom hyaluronidase. In specific embodiments, a nucleic acid molecule of the invention encodes an immunomodulatory portion of a T cell epitope of a *Polistinae* venom enzyme. In another embodiment, a nucleic acid molecule of the invention encodes an antigenic portion of a B cell epitope of a *Polistinae* venom enzyme.

The nucleic acids of the invention, which are not genomic, surprisingly are found, in one embodiment, to contain a non-coding, e.g., intronic sequences. In a specific embodiment, cDNA molecules for *Polistinae* venom enzyme contain what appears to be an intron. Thus, it has unexpectedly proved necessary to delete these "intronic" sequences in order to obtain a nucleic acid coding for a mature *Polistinae* venom enzyme, e.g., phosholipase or hyaluronidase.

Hence broadly, the present invention extends to an isolated nucleic acid molecule encoding a venom enzyme, conserved variant thereof, immunomodulatory fragment thereof, or derivative, or analog thereof. As noted above, the nucleic acid molecule contains internal non-coding sequences, i.e., in addition to 5' and 3' untranslated (UTR) sequences., but is not a genomic sequence. Examples of *Polistinae* venom enzymes which can be encoded by an isolated nucleic acid molecule of the invention include, but are not limited to phospholipase and hyaluronidase. Moreover, enzymes, conserved variants thereof, immunomodulatory fragments thereof, or analogs or derivatives thereof, from the venom of numerous *Polistinae* venoms can be encoded by an isolated nucleic acid molecule of the invention. A particular example comprises *Polistinae* of the genus *Polistes*, and

particularly the species *annularis*.

In a particular embodiment, the present invention extends to an isolated nucleic acid molecule encoding a phospholipase A_1, conserved variants thereof, immunomodulatory fragments thereof, or analogs or derivatives thereof, from the genus *Polistes* and the species *annularis*, wherein the *P. annularis* has an amino acid sequence as depicted in SEQ ID NO:2, and more specifically, wherein the isolated nucleic acid molecule has a nucleotide sequence of SEQ ID NO:1, degenerate variants thereof, fragments thereof, or analogs or derivatives thereof.

In another particular embodiment, the present invention extends to an isolated nucleic acid molecule, that encodes hyaluronidase from *Polistes annularis* comprising an amino acid sequence of SEQ ID NO: 4, more particularly wherein the isolated nucleic acid has a nucleotide sequence of SEQ ID NO:3, degenerate variants thereof, fragments thereof, or analogs or derivatives thereof, conserved variants thereof, immunomodulatory fragments thereof, or analogs or derivatives thereof.

Moreover, the present invention extends to an isolated nucleic acid molecule hybridizable to an isolated nucleic acid molecule comprising a DNA sequence of SEQ ID NO:1 or 3, degenerate variants thereof, fragments thereof, or analogs or derivatives thereof.

Moreover, the present invention further extends to an isolated nucleic acid molecule encoding a *Polistinae* venom enzyme, or an immunomodulatory fragment, derivative or analog thereof, wherein the isolated nucleic acid molecule encodes an immunomodulatory portion of a T cell epitope or an antigenic portion of a B cell epitope of the *Polistinae* venom enzyme. Likewise, the present invention extends to an isolated polypeptide comprising an immunomodulatory portion of a T cell epitope of a *Polistinae* venom enzyme, wherein the polypeptide is encoded by an isolated nucleic acid molecule of the invention. Examples of waso venom enzymes for which isolated nucleic acid molecules of the present invention encode an immunomodulatory portion of a T cell epitope include, but certainly are not limited to, phospholipase and hyaluronidase. In a specific embodiment, the phospholipase A_1 and hyaluronidase originate from a genus *Polistes,* and particularly from the species *annularis*.

The invention further provides cloning vectors and expression vectors, which permit expression of the nucleic acids. Such vectors contain nucleic acids of the invention

as set forth above. In the case of expression vectors, such nucleic acids are operatively associated with an expression control sequence.

The invention advantageously provides a method of producing a *Polistinae* venom phospholipase, conserved variant thereof, immunomodulatory fragment thereof, or analog or derivative thereof, which is encompassed by the present invention, comprises:

(a) culturing a host cell transformed with an expression vector comprising an isolated nucleic acid molecule hybridizable to an isolated nucleic acid molecule comprising a DNA sequence of SEQ ID NO:1, preferably having a sequence of SEQ ID NO:1, degenerate variants thereof, fragments thereof, or analogs or derivatives thereof, wherein the isolated nucleic acid molecule is operationally associated with a promoter, so that the *Polistinae* venom phospholipase, conserved variant thereof, immunomodulatory fragment thereof, or analog or derivative thereof, is produced by the host cell; and

(b) recovering the *Polistinae* venom phospholipase, conserved variant thereof, immunomodulatory fragment thereof, or analog or derivative thereof so produced from the culture, the host cell, or both.

Another method is provided for producing a *Polistinae* venom hyaluronidase, conserved variants thereof, immunomodulatory fragments thereof, or analogs or derivatives thereof, comprises the steps of:

(a) culturing a host cell transformed with an expression vector comprising an isolated nucleic acid molecule hybridizable to an isolated nucleic acid molecule comprising a DNA sequence of SEQ ID NO:3, or preferably having a sequence of SEQ ID NO:3, degenerate variants thereof, fragments thereof, or analogs or derivatives thereof, wherein the isolated nucleic acid molecule is operationally associated with a promoter, so that the *Polistinae* venom hyaluronidase, conserved variant thereof, immunomodulatory fragment thereof, or analog or derivative thereof is produced by the host cell; and

(b) recovering the *Polistinae* venom hyaluronidase, conserved variant thereof, immunomodulatory fragment thereof, or analog or derivative

thereof so produced, from the culture, the host cell, or both.

In a particular example, the methods set forth above yield phospholipase A_1 or hyaluronidase of the genus *Polistes*, and particularly from the species *annularis*, wherein the phospholipase A_1 comprises an amino acid sequence of SEQ ID NO:2, conserved variants thereof, immunomodulatory fragments thereof, or analogs or derivatives thereof, and the hyaluronidase comprises an amino acid sequence of SEQ ID NO:4, conserved variants thereof, immunomodulatory fragments thereof, or analogs or derivatives thereof.

The present invention further extends to pharmaceutical compositions effective for the treatment of a venom allergen-specific allergic condition. In particular, the present invention extends to a pharmaceutical composition comprising a polypeptide encoded by an isolated nucleic acid molecule which encodes an immunomodulatory portion of a T cell or an antigenic portion of a B cell epitope of a *Polistinae* venom enzyme, *e.g.*, phospholipase or hyaluronidase, and a pharmaceutically acceptable carrier thereof. Consequently, in a preferred embodiment, a pharmaceutical composition of the invention comprises an immunomodulatory T cell epitope of *Polistes annularis* venom phospholipase A_1, or hyaluronidase or an antigenic portion of a B cell epitope of *Polistes annularis* phospholipase A_1, or hyaluronidase.

Naturally, the present invention extends to a method for treating a vespid venom allergen-specific allergic condition comprising administering a therapeutically effective amount of a pharmaceutical composition of the invention, examples of which are set forth above. Administration of a pharmaceutical composition of the invention can occur parenterally, and particularly orally, pulmonarily, nasally, topically or systemically.

Furthermore, the present invention extends to use of a recombinant *Polistinae* venom enzyme of the invention in the manufacture of a medicament for, and an associated method for modulating an immune response towards an immunogen, *e.g.*, treating a vespid allergic condition or treating an immune system related disease or disorder or a symptom of the immune system related disease or disorder. The polypeptide is encoded by an isolated nucleic acid molecule which encodes a *Polistinae* venom enzyme, wherein the polypeptide comprises an immunomodulatory fragment of a *Polistinae* venom enzyme. More particularly, an agent for treating an immune system related disease or disorder, or symptom related thereto, comprises a *Polistinae* venom enzyme or a vector that permits expression of the *Polistinae* venom or enzyme *in vivo*.

In a specific embodiment, the polypeptide is a phospholipase encoded by an isolated nucleic acid molecule hybridizable to, or preferably, comprising a DNA sequence of SEQ ID NO:1, degenerate variants thereof, fragments thereof, or analogs or derivatives thereof.

Hence, an agent for treating an immune system related disorder or disease, or a symptom thereof, comprises an isolated polypeptide encoded by an isolated nucleic acid molecule which encodes a *Polistinae* venom hyaluronidase, conserved variants thereof, immunomodulatory fragments thereof, or analogs or derivatives thereof.

In another embodiment, the polypeptide is a hyaluronidase encoded by an isolated nucleic acid molecule hybridizable to, and preferably comprising, a DNA sequence of SEQ ID NO:3, degenerate variants thereof, fragments thereof, or analogs or derivatives thereof.

Furthermore, the present invention extends to a pharmaceutical composition for modulating an immune response towards an immunogen, *e.g.*, treating a vespid allergic condition or treating an immune system related disease or disorder or a symptom related thereto, wherein the pharmaceutical composition comprises a recombinant *Polistinae* venom enzyme and a pharmaceutically acceptable carrier thereof.

Administration of a pharmaceutical composition for treating an immune system related disease or disorder to a subject can be carried out parenterally, and particularly orally, pulmonarily, nasally, topically or systemically. Furthermore, numerous diseases or disorders related to the immune system can be treated with the present invention. Examples include, but are no limited to, a pathogenic disease or disorder such as a viral disease or disorder, *e.g.*, HIV, Herpes Simplex virus, or papiloma virus; an autoimmune disease *e.g.* arthritis or Lupus; or a combination of such diseases or disorders.

It is a specific object of the invention to provide the surprising DNA sequence of isolated nucleic acid (cDNA) molecules that encode *Polistes annularis* hyaluronidase, conserved variants thereof, fragments thereof, or analogs or derivatives thereof.

It is still yet another object of the invention to provide amino acid sequences of *Polistes annularis* phospholipase A_1 and hyaluronidase, along with conserved variants thereof, fragments thereof, including immunomodulatory portions of T cell epitopes and antigenic portions of B cell epitopes of *Polistes annularis* phospholipase A_1 and

hyaluronidase, either containing, or more preferably free, of "intronic" sequence. The deduced amino acid sequences of phospholipase A_1 and hyaluronidase from *Pol a* allow comparison of their homology to analogous enzymes from other vespids. This information provides a basis for evaluating cross-reactivity of the allergens, which can be important for allergic reactions and for therapeutic treatments. Hence, in a specific embodiment, the present invention enables one of ordinary skill in the art to determine and evaluate the degree of similarity of phospholipase A_1 and hyaluronidase of *Pol a* to environmental proteins and/or autologous proteins. It is believed that similarity of the vespid venom enzymes to such environmental proteins, and particularly to autologous proteins, has important implications for the allergic response.

It is yet still another object of the invention to provide expression and cloning vectors comprising an isolated nucleic acid molecule encoding *Polistes annularis* phospholipase A_1 and hyaluronidase, including fragments comprising an immunomodulatory portion of a T cell epitope or an antigenic portion of a B cell epitope of these *Polistinae* venom enzymes so that the isolated nucleic acid molecules can be reproduced and expressed.

Yet another object of the invention comprises production of *Polistinae* venom enzymes such as phospholipase and hyaluronidase, along with conserved variants thereof, immunomodulatory fragments thereof, or analogs or derivatives thereof, using expression vectors of the invention, despite the presence of intronic sequences in cDNA clones

Yet still another object of the invention is to provide agents and pharmaceutical compositions for treating an allergen-specific allergic condition in a subject, wherein the agents and pharmaceutical composition comprise an isolated polypeptide encoded by an isolated nucleic acid molecules which encodes a *Polistinae* venom enzyme, such as phospholipase or hyaluronidase, particularly from *Polistes annularis*, wherein the polypeptide comprises an antigen portion of a B cell epitope, or an immunomodulatory portion of a T cell epitope of, a *Polistinae* phospholipase A_1 or hyaluronidase.

Yet still another object of the invention is to provide a method for treating a vespid venom allergen-specific allergy in a subject, wherein a pharmaceutical composition for treating an allergen-specific allergic condition is administered to the subject.

Yet still another object of the invention is to provide agents and

pharmaceutical compositions comprising such agents that treat an immune system related disease or disorder in mammal, such as a pathogenic disease or disorder, a viral disease or disorder, an autoimmune disease or disorder, or a combination of immune system related diseases or disorders.

Still yet another object of the invention is to provide agents and pharmaceutical composition for modulating immune response towards an immunogen in a mammal. As a result, administration of such a pharmaceutical composition modulates the immune system's ability to recognize and attack the immunogen. In a particular embodiment, the ability of the immune system of the mammal to recognize and attack the immunogen is increased upon administration of the pharmaceutical composition relative to the ability of the subject's immune system to recognize and attack the immunogen prior to administration of a pharmaceutical composition of the invention.

ABBREVIATIONS

Dol m	*Dolichovespula maculata*	white face hornet
Dol a	*D. arenaria*	yellow hornet
Pol a	*Polistes annularis*	wasp
Pol e	*P. exclamans*	wasp
Ves m	*Vespula maculifrons*	yellow jacket
Ves v	*V. vulgaris*	yellow jacket
PCR		polymerase chain reaction
RACE		rapid amplification of cDNA ends
TCR		T cell receptor for antigen

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1A-B. The cDNA nucleotide sequence encoding *Pol a* venom phospholipase A_1 (SEQ ID NO:1) and the amino acid sequence of *Pol a* venom phospholipase A_1 (SEQ ID NO:2). Note that the first 18 amino acid residues of SEQ ID NO:2 represent a portion of a signal sequence. Hence, amino acid residue 19 of SEQ ID

NO:2 (glycine) is the N-terminus amino acid residue in mature *Pol a* phospholipase A_1.

Figures 2A and 2B. *Pol a* phospholipase cDNA contains two introns. **(A)** The nucleotide sequence of *papla intron 1* (SEQ ID NO:5), an intron in *Pol a* venom phospholipase A_1 cDNA located between nucleotides 111 and 112 of SEQ ID NO:1. **(B)** The nucleotide sequences of *papla intron 2* (SEQ ID NO:6), an intron in *Pol a* venom phospholipase A_1 cDNA located between nucleotides 720 and 721 of SEQ ID NO:1.

Figure 3A-B. Amino acid residue sequence similarity among hornet venom phospholipase (SEQ ID NO:7), yellowjacket phospholipase (SEQ ID NO:8) and paper wasp phospholipase A_1 (SEQ ID NO:2).

Figure 4A-C. The cDNA nucleotide sequence encoding *Pol a* venom hyaluronidase (SEQ ID NO:3) and the amino acid sequence of *Pol a* hyaluronidase (SEQ ID NO:4). Note that the first 23 amino acid residues of SEQ ID NO:4 represent a portion of a signal sequence. Hence, amino acid residue 30 of SEQ ID NO:4 (serine) is the N-terminus amino acid residue of mature *Pol a* hyaluronidase.

Figure 5. The nucleotide sequence of *Pahya* (SEQ ID NO:9), an intron in *Pol a* hyaluronidase cDNA, located between nucleotides 733 and 734 of SEQ ID NO:3.

Figure 6A-B. Amino acid residue sequence similarity among bee venom (bv) hyaluronidase (SEQ ID NO:10), *Dol m* (wfh) hyaluronidase (SEQ ID NO:11), *Ves v* (vv) hyaluronidase (SEQ ID NO:12), and *Pol a* (pa) hyaluronidase (SEQ ID NO:4).

DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed to recombinant nucleic acid molecules encoding *Polistinae* venom enzymes, such as phospholipase and hyaluronidase, and immunomodulatory fragments, derivatives or analogs thereof, and polypeptides encoded by such nucleic acid molecules useful in the diagnosis and therapy of vespid venom-specific allergy. In specific embodiments, the present invention is directed to a recombinant nucleic acid molecule encoding an immunomodulatory fragment of a *Polistinae* phospholipase, in particular *Pol a* phospholipase A_1, immunomodulatory fragments thereof, analogs or derivatives thereof, and *Pol a* hyaluronidase, conserved variants thereof, immunomodulatory fragments thereof, and analogs or derivatives thereof.

The present invention is based, in part, on the surprising and wholly unexpected discovery of internal non-coding segments of cDNAs encoding both *Pol a*

phospholipase and *Pol a* hyaluronidase. Prior to this discovery, cDNAs for vespid venom enzymes did not contain such apparent "intronic" sequences.

This discovery has two significant implications. The first is that *Polistinae*, and more particularly, *Polistes*, and more particularly still, *Pol a*, cDNAs appear to contain "introns". Thus, *Polistinae*s of this subfamily express unique mRNAs, have unique mRNA processing capabilities, and potentially represent interesting splice variants.

The term "introns" is used to refer to nucleic acid sequences that are not expected to be present in a cDNA coding for phospholipase or hyaluronidase, and that are not 5' or 3' UTR sequences. The sequences may represent unexpected splice variants of the proteins, incomplete processing of mRNAs, or some regulatory feature found in this subfamily, genus, and species of vespid.

The presence of these "intron" sequences significantly impacts preparation of expression vectors. While it is possible to express the unique polypeptides encoded by these cDNAs, in another embodiment an unpredictable modification of the cDNA is required to eliminate these "introns" in order to express mature forms of the *Polistinae* venom enzymes, *e.g.*, for use in immunotherapy. Thus, it has unexpectedly proven necessary to further engineer coding sequences for *Polistinae* phospholipase and hyaluronidase. Once these "intron" sequences are deleted, phospholipase or hyaluronidase proteins comprising the natural amino acid sequence can be obtained.

The invention is further directed to expression vectors comprising such nucleic acid molecules, and to methods for producing *Polistinae* venom enzyme polypeptides of the invention by expressing such expression vectors and recovering the produced *Polistinae* venom enzyme polypeptides.

The invention also provides pharmaceutical compositions effective for the treatment of a vespid venom, and likely even a hymenoptera venom, allergen-specific allergic condition comprising a polypeptide of the invention, and methods for treating such allergic conditions comprising administering a therapeutically effective amount of the pharmaceutical compositions of the invention.

The polypeptides of the invention can also be useful for diagnosis of vespid, particularly *Polistinae* , venom-specific allergic conditions.

In addition, it has been discovered that, unexpectedly, administration of a pharmaceutical compositions comprising *Polistinae* venom phospholipase or hyaluronidase

be used to treat an immune system related disease or disorder, such as a pathogenic disease or disorder, a viral disease or disorder, an autoimmune disease or disorder, or a combination of such diseases or disorders.

Accordingly, as used herein, the term "*Polistinae* venom allergen" refers to a protein found in the venom of a *Polistinae*, such as the paper wasp (*Polistes annularis*), to which susceptible people are sensitized on exposure to the sting of the insect. While most antigens are characterized by being reactive with specific IgG class antibodies, an allergen is characterized by also being reactive with IgE type antibodies. The IgE type antibodies are responsible for mediating the symptoms of an allergic condition, *i.e.*, immediate-type hypersensitivity.

As used herein, the term "vespid" is used according to the practice of those in the field of allergy, and refers to insects belonging to the worldwide family of Vespidae, *i.e.*, social wasps including hornets, yellowjackets, and paper wasps. In particular, vespids of the subfamily *Vespinae* include the subfamilies *Vespinae* and *Polistinae*. More particularly, the vespids of the subfamily include the genera *Vespa* Linnaeus, *Vespula* Thomson, *Dolichovespula* Rohwer, and *Polistes* Latreille. *Vespula* and *Dolichovespula* can be considered subgenera of the genus *Vespula* Species in the genus *Vespa* include but are not limited to *V. crabro* (L.) and *V. orientalis* (Linnaeus). Species in the genus *Vespula* include but are not limited to *V. germanica* (Fab.), *V. squamosa* (Drury), *V. maculifrons* (Buysson), *V. flavopilosa* (Jacobson), *V. vulgaris* (L.), and *V. pensylvanica* (Saussure). Species in the genus *Dolichovespula* include but are not limited to *P. dominulus*, *D. maculata* (L.) and *D. arenaria* (Fab.).

The subfamily *Polistinae* includes the genus *Polistes*. Species in the genus *Polistes* include but are not limited to *P. dominulus*, *Pol a* (Linnaeus), *P. exclamans* (Viereck), *P. metricus* (Say), *P. fuscatus* (Fabricius), *P. gallicus*, pacificus, *P. canadensis*, *P. kaibabensis*, *P. comanchus*, *P. commanchus*, *P. annularis*, *P. exclamans*, *P. instabilis*, *P. carnifex*, *P. major*, *P. metricus*, *P. perplexus*, *P. carolinus*, *P. flavus*, *P. fuscatus*, *P. aurifer*, *P. dorsalis*, *P. bellicosus*, *P. apachus*, *P. sulcifer*, *P. semenowi*, *P. atrimandibularis*, *P. biglumis*, *P. bischoffi*, *P. dominulus*, *P. nimpha*, *P. Pgallicus*, *P. associus*, *P. gigas*, *P. stigma*, *P. adustus*, *P. snelleni*, *P. mandarinus*, *P. chinensis*, *P. sulcatus*, *P. formosanus*, *P. japonicus*, *P. watttii*, *P. macaensis*, *P. jadwigae*, *P. olivaceus*, *P. rothneyi*, *P. jokohamae*, *P. poeyi*, *P. paraguayensis*, *P. rossi*, *P. cinctus*,

P. cavapyta, *P. buysonni*, *P. brevifissus*, *P. ferreri*, *P. infuscatus*, *P. satan*, *P. melanotus*, *P. erythrocephalus*, *P. lanio*, *P. penai*, *P. aterrimus*, *P. huacapistana*, *P. versicolor*, *P. ninabamba*, *P. simillimus*, *P. adelphus*, *P. biguttatus*, *P. binotatus*, *P. consobrinus*, *P. peruvianus*, *P. weyrauchorum*, *P. xanthogaster*, *P. maranonensis*, *P. myersi*, *P. veracrucis*, *P. eburneus*, *P. stabilinus*, *P. pseudoculatus*, *P. apicalis*, *P. oculatus*, *P. crinitus*, *P. cubensis*, *P. minor*, *P. incertus*, *P. franciscanus*, *P. goeldii*, *P. olivaceus*, *P. bicolor*, *P. thoracicus*, *P. rufiventrus*, *P. moraballi*, *P. angulinus*, *P. subsericeus*, *P. testaceicolor*, *P. claripennis*, *P. billardieri*, *P. davillae*, *P. occipitalis*, *P. atrox*, *P. deceptor*, *P. niger*, *P. candidoi*, *P. geminatus*, *P. melanosoma*, *P. actaeon*, *P. obscurus*, *P. bequaertianus*, *P. cinerascens*, and *P. apachus* (Saussure).

As used herein, the term "phospholipase" refers to the class of enzymes that act on phospholipid substrates, *e.g.*, to hydrolyze fatty acids. In a specific embodiment a phospholipase catalyzes rapid hydrolysis of the acyl group at position 1 of synthetic phosphatidylcholines, and a slow hydrolysis of the acyl group at position 2. Thus, the vespid phospholipases of the invention can have both A_1 and B types of phospholipase activities. The phospholipases of the invention can have low level lipase activity as well.

As used herein, the term "hyaluronidase" refers to the class of enzymes that act on the disaccharide unit of D-glucuronic acid and N-acetyl-D-glucosamine. Such enzymes mediate the hydrolysis of polymers of repeating disaccharides comprising D-glucuronic acid and N-acetyl-D-glucosamine. One example of such polymer is hyaluronic acid. Hyaluronidase catalyzes the release of reducing groups of N-acetylglucosamine from hyaluronic acid.

A "genomic" sequence contains all introns 5' and 3' untranslated sequences, and 5' and 3' untranscribed, (and often regulatory) sequences of a gene. Thus, a coding sequence is not genomic when it lacks one or more introns and 5' and 3' untranscribed sequences, particularly regulatory sequences.

As used herein, the term "immunomodulatory" refers to an ability to increase or decrease an antigen-specific immune response, either at the B cell or T cell level. Immunomodulatory activity can be detected *e.g.*, in T cell proliferation assays, by measurement of antibody production, lymphokine production or T cell responsiveness. In particular, in addition to affects on T cell responses, the immunomodulatory polypeptides of the invention may bind to immunoglobulin (*i.e.*, antibody) molecules on the surface of B

cells, and affect B cell responses as well.

As used herein, the term "derivative" refers to a modified nucleic acid encoding a *Polistinae*, particularly a *Polistes*, phospholipase or hyaluronidase venom enzyme that contains a substitution, deletion, or insertion, and the protein encoded thereby. The term "derivative" specifically refers to a low IgE binding derivative (or analog) that contains amino acid substitutions at key amino acid residues, resulting in reduced IgE binding without disrupting the overall conformation or secondary and tertiary structure of the protein. Low IgE binding derivatives are described in PCT/DK99/00136.

As used herein, the phrase "immune system related disease or disorder" refers to a disease or disorder which evokes an immune response in a subject, or effects the ability of the immune system to respond to an immunogen. Hence, examples of immune system related diseases or disorders comprise a pathogenic disease or disorder; a viral disease or disorder, *e.g.* HIV, Herpes Simplex virus, or papiloma virus; an autoimmune disease, *e.g.* arthritis or Lupus.

A "nucleic acid molecule" refers to the phosphate ester polymeric form of ribonucleosides (adenosine, guanosine, uridine or cytidine; "RNA molecules") or deoxyribonucleosides (deoxyadenosine, deoxyguanosine, deoxythymidine, or deoxycytidine; "DNA molecules") in either single stranded form, or a double-stranded helix. Double stranded DNA-DNA, DNA-RNA and RNA-RNA helices are possible. The term nucleic acid molecule, and in particular DNA or RNA molecule, refers only to the primary and secondary structure of the molecule, and does not limit it to any particular tertiary forms. Thus, this term includes double-stranded DNA found, *inter alia*, in linear or circular DNA molecules (e.g., restriction fragments), viruses, plasmids, and chromosomes. In discussing the structure of particular double-stranded DNA molecules, sequences may be described herein according to the normal convention of giving only the sequence in the 5' to 3' direction along the nontranscribed strand of DNA (i.e., the strand having a sequence homologous to the mRNA). A "recombinant DNA molecule" is a DNA molecule that has undergone a molecular biological manipulation.

A nucleic acid molecule is "hybridizable" to another nucleic acid molecule, such as a cDNA, genomic DNA, or RNA, when a single stranded form of the nucleic acid molecule can anneal to the other nucleic acid molecule under the appropriate conditions of temperature and solution ionic strength (*see* Sambrook et al., *supra*). The conditions of

temperature and ionic strength determine the "stringency" of the hybridization. For preliminary screening for homologous nucleic acid molecules, low stringency hybridization conditions, corresponding to a T_m of 55°, can be used, *e.g.*, 5x SSC, 0.1% SDS, 0.25% milk, and no formamide; or 30% formamide, 5x SSC, 0.5% SDS). Moderate stringency hybridization conditions correspond to a higher T_m (about 60°), *e.g.*, 40% formamide, with 5x or 6x SSC. High stringency hybridization conditions correspond to the highest T_m (greater than or equal to about 65°), *e.g.*, 50% formamide, 5x or 6x SSC. Hybridization requires that the two nucleic acid molecules contain complementary sequences, although depending on the stringency of the hybridization, mismatches between bases are possible. The appropriate stringency for hybridizing nucleic acid molecules depends on the length of the nucleic acid molecules and the degree of complementation, variables well known in the art. The greater the degree of similarity or homology between two nucleotide sequences, the greater the value of T_m for hybrids of nucleic acid molecules having those sequences. The relative stability (corresponding to higher T_m) of nucleic acid hybridizations decreases in the following order: RNA:RNA, DNA:RNA, DNA:DNA. For hybrids of greater than 100 nucleotides in length, equations for calculating T_m have been derived (*see* Sambrook et al., *supra*, 9.50-0.51). For hybridization with shorter nucleic acid molecules, *i.e.*, oligonucleotides, the position of mismatches becomes more important, and the length of the oligonucleotide determines its specificity (*see* Sambrook et al., *supra*, 11.7-11.8). Preferably a minimum length for a hybridizable nucleic acid molecule is at least about 10 nucleotides; preferably at least about 10 nucleotides; and more preferably the length is at least about 20 nucleotides; even more preferably 30 nucleotides; and most preferably 40 nucleotides.

In a specific embodiment, the term "standard hybridization conditions" refers to a T_m of 55°C, and utilizes conditions as set forth above. In a preferred embodiment, the T_m is 60°C; in a more preferred embodiment, the T_m is 65°C.

A DNA "coding sequence" is a double-stranded DNA sequence which is transcribed and translated into a polypeptide *in vivo* when placed under the control of appropriate regulatory sequences. The boundaries of the coding sequence are determined by a start codon at the 5' (amino) terminus and a translation stop codon at the 3' (carboxyl) terminus. A coding sequence can include, but is not limited to, prokaryotic sequences, cDNA from eukaryotic mRNA, genomic DNA sequences from eukaryotic (e.g.,

mammalian) DNA, and even synthetic DNA sequences. If the coding sequence is intended for expression in a eukaryotic cell, a polyadenylation signal and transcription termination sequence will usually be located 3' to the coding sequence.

Transcriptional and translational control sequences are DNA regulatory sequences, such as promoters, enhancers, terminators, and the like, that provide for the expression of a coding sequence in a host cell. In eukaryotic cells, polyadenylation signals are control sequences.

A "promoter sequence" is a DNA regulatory region capable of binding RNA polymerase in a cell and initiating transcription of a downstream (3' direction) coding sequence. For purposes of defining the present invention, the promoter sequence is bounded at its 3' terminus by the transcription initiation site and extends upstream (5' direction) to include the minimum number of bases or elements necessary to initiate transcription at levels detectable above background. Within the promoter sequence will be found a transcription initiation site (conveniently defined for example, by mapping with nuclease S1), as well as protein binding domains (consensus sequences) responsible for the binding of RNA polymerase. Eukaryotic promoters will often, but not always, contain "TATA" boxes and "CAT" boxes.

A coding sequence is "under the control" of transcriptional and translational control sequences in a cell when RNA polymerase transcribes the coding sequence into mRNA, which is then translated into the protein encoded by the coding sequence.

A "signal sequence" can be included before the coding sequence. This sequence encodes a signal peptide, N-terminal to the polypeptide, that directs the host cell to transport the polypeptide to the cell surface or secrete the polypeptide into the media, and this signal peptide is usually selectively degraded by the cell upon exportation. Signal sequences can be found associated with a variety of proteins native to prokaryotes and eukaryotes.

In accordance with the present invention there may be employed conventional molecular biology, microbiology, and recombinant DNA techniques within the skill of the art. Such techniques are explained fully in the literature. See, *e.g.*, Sambrook, Fritsch & Maniatis, "Molecular Cloning: a Laboratory Manual," Second Edition (1989) Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York (herein "Sambrook et al., 1989"); "DNA Cloning: a Practical Approach," Volumes I and II (D.N. Glover ed.

1985); "Oligonucleotide Synthesis" (M.J. Gait ed. 1984); "Nucleic Acid Hybridization" [B.D. Hames & S.J. Higgins eds. (1985)]; "Transcription And Translation" [B.D. Hames & S.J. Higgins, eds. (1984)]; "Animal Cell Culture" [R.I. Freshney, ed. (1986)]; "Immobilized Cells And Enzymes" [IRL Press, (1986)]; B. Perbal, "a Practical Guide To Molecular Cloning" (1984).

The present invention is based, in part, on the cloning and sequence determination of a *Polistinae* venom phospholipase and hyaluronidase. The cloning and sequence determination of this *Polistinae* venom enzymes is highly significant, since the cDNA clones unexpectedly contain extra nucleotide sequences that do not appear to encode polypeptide . Vespid venom allergic conditions are common, and in some sensitive individuals an allergic reaction can proceed to anaphylaxas, which is potentially fatal. As with vespids in general, *Polistinae* venom components are likely to play an important role in production of allergin. It is therefore of great importance that the nucleotide and amino acid sequence information for the *Polistinae* venom allergens is known so that accurate diagnostic information about the nature of the allergic condition, especially specific allergen sensitivities, can be determined and effective therapeutic treatments of the underlying allergic condition can be effected. It has unexpectedly been the casxe here, since *Polistinae* cDNAs were surprisingly found with non-transcribed sequences.

Isolation of a Nucleic Acid Molecule Encoding a Wasp Venom Enzyme

Isolation of nucleic acid molecules encoding vespid venom enzymes was fully described in U.S. Patent No. 5,593,877. The present invention concerns the unexpected and surprising discoveries that *Polistinae* cDNAs contain "introns". Typically, introns are spliced out of mRNA and are, therefore, not usually found in cDNAs. The sequences may represent splice variants.

Derivatives of a *Polistinae* venom enzyme, fragments, and fusion proteins (see *infra*), are additionally provided, as well as nucleic acid molecules encoding the same.

In a preferred aspect, the present invention provides the complete nucleic acid sequence of a *Polistinae* venom enzyme. In particular, the present invention provides the nucleic acid sequence of a *Polistinae* phospholipase, in particular *Pol a* (paper wasp) phospholipase A_1, and hyaluronidase, in particular *Pol a* hyaluronidase.

In a specific embodiment, to obtain a nucleic acid molecule encoding a *Polistinae* venom enzyme, polymerase chain reaction (PCR) is combined with the rapid

amplification of cDNA ends (RACE) technique described by Frohman et al. (Proc. Nat. Acad. Sci. USA , 1998, 85:8998-9002; see also Frohman, 1990, Amplifications: A Forum for PCR Users 5:11) to amplify a fragment encoding a sequence comprising the *Polistinae* venom enzyme prior to selection. Oligonucleotide primers representing a *Polistinae* venom enzyme of the invention can be used as primers in PCR. Generally, such primers are prepared synthetically. Sequences for such oligonucleotide primers can be deduced from amino acid sequence information. Such oligonucleotide sequences may be non-degenerate, but more frequently the sequences are degenerate. More preferably, the primers are based on the nucleic acid sequences for the *Polistinae* venom enzymes disclosed herein. The oligonucleotides may be utilized as primers to amplify by PCR sequences from a source (RNA or DNA), preferably a cDNA library, of potential interest. For example, PCR can be used to amplify a *Polistinae* venom enzyme coding sequence from a *Polistinae* acid gland cDNA library. PCR can be carried out, *e.g.*, by use of a Perkin-Elmer Cetus thermal cycler and Taq polymerase (Gene Amp™).

The present invention further provides for isolating a homolog of a *Polistinae* venom enzyme from any species of *Polistinae* . One can choose to synthesize several different degenerate primers for use, *e.g.*, in PCR reactions. It is also possible to vary the stringency of hybridization conditions used in priming PCR reactions, to allow for greater or lesser degrees of nucleotide sequence similarity between a homolog of a *Polistinae* venom enzyme and a specific *Polistinae* venom enzyme disclosed herein. After successful amplification of a segment of a homolog of a *Polistinae* venom enzyme, that segment may be cloned and sequenced, and utilized as a probe to isolate a complete cDNA or genomic clone. This, in turn, will permit the determination of the complete nucleotide sequence, the analysis of its expression, and the production of its protein product for functional analysis, as described *infra*. In this fashion, additional genes encoding *Polistinae* venom enzymes, in particular, phospholipases and hyaluronidases, may be identified and expressed.

In another embodiment, genes encoding a *Polistinae* venom enzyme can be isolated from a suitable library by screening with a probe. Useful probes for isolating a *Polistinae* venom enzyme gene can be generated from the sequence information provided herein.

An expression library can be constructed by methods known in the art.

Preferably, a cDNA library is prepared from cells or tissues that express a *Polistinae* venom enzyme, *i.e.*, cells from the poison gland located near the venom sac. Sometimes the poison gland is referred to as the acid gland. For example, mRNA or total RNA can be isolated, cDNA is made and ligated into an expression vector (*e.g.*, a plasmid or bacteriophage derivative) such that it is capable of being expressed by the host cell into which it is then introduced. Various screening assays can then be used to select for the positive clones. For example, PCR with appropriate primers, which can be synthesized based on the sequences provided herein, can be used. PCR is preferred as the amplified production can be directly detected, e.g., by ethydium bromide staining. Alternatively, labeled probes derived from the nucleic acid sequences of the instant application can be used to screen the colonies. Although the poison (acid) gland can be difficult to isolate, and the quantity of mRNA problematic, specific PCR based on primers of the present invention can overocme these problems by permitting specific amplification of trace amounts of mRNA or cDNA or even genomic DNA.

Alternatively, the presence of the gene may be detected by assays based on the physical, chemical, or immunological properties of its expressed product. For example, cDNA clones, or DNA clones which hybrid-select the proper mRNAs, can be selected which produce a protein that, *e.g.*, has similar or identical electrophoretic migration, isoelectric focusing behavior, proteolytic digestion maps, or antigenic properties as known for a *Polistinae* venom enzyme.

Some recombinant proteins expressed by bacteria, *e.g.*,*Polistinae* venom hyaluronidases, may react with antibodies specific for the native proteins. Other bacterially expressed recombinant proteins, such as venom phospholipases, may not react with antibodies specific for the native protein. Thus, in cases where the recombinant proteins are immunoreactive, it is possible to select for positive clones by immunoblot.

In another embodiment, the specific catalytic activity of the enzyme, such as lipase activity of an expressed *Polistinae* venom phospholipase, can be used for selection. However, bacterially expressed eukaryotic proteins may not fold in an active conformation.

Generally, according to the present invention, any method of screening for positive clones can be used.

Alternatives to isolating the *Polistinae* venom enzyme genomic DNA or cDNA include, but are not limited to, chemically synthesizing the gene sequence itself from

the sequence provided herein.

The above methods are not meant to limit the methods by which clones of a *Polistinae* venom enzyme may be obtained.

A large number of vector-host systems known in the art may be used. Possible vectors include, but are not limited to, plasmids or modified viruses, but the vector system must be compatible with the host cell used. Such vectors include, but are not limited to, bacteriophages such as lambda derivatives, or plasmids such as various pBR322 derivatives, for example, pUC, CR, pGEX vectors, pmal-c, pFLAG, etc. The insertion into a cloning vector can, for example, be accomplished by ligating the DNA fragment into a cloning vector which has complementary cohesive termini. In a preferred aspect of the invention, the PCR amplified nucleic acid molecules of the invention contain 3'-overhanging A-nucleotides, and can be used directly for cloning into a pCR vector with compatible T-nucleotide overhangs (Invitrogen Corp., San Diego, CA). However, if the complementary restriction sites used to fragment the DNA are not present in the cloning vector, the ends of the DNA molecules may be enzymatically modified. Alternatively, any site desired may be produced by ligating nucleotide sequences (linkers) onto the DNA termini; these ligated linkers may comprise specific chemically synthesized oligonucleotides encoding restriction endonuclease recognition sequences. In an alternative method, the cleaved vector and a *Polistinae* venom enzyme gene may be modified by homopolymeric tailing. Recombinant molecules can be introduced into host cells via transformation, transfection, infection, electroporation, etc., so that many copies of the gene sequence are generated.

In specific embodiments, transformation of host cells with recombinant DNA molecules that incorporate the isolated *Polistinae* venom enzyme gene, cDNA, or synthesized DNA sequence enables generation of multiple copies of the gene. Thus, the gene may be obtained in large quantities by growing transformants, isolating the recombinant DNA molecules from the transformants and, when necessary, retrieving the inserted gene from the isolated recombinant DNA.

Expression of a Polistinae Venom Allergen Polypeptide or Fragment

As pointed out above, the isolated nucleic acids encoding *Polistinae* venom

enzymes, particularly *Polistes* venom proteins, contain unexpected sequences that should be absent for the cDNA to encode a protein similar to other *Polistinae* venom enzymes, *e.g.*, as described in U.S. Patent No. 5,593,877. In one embodiment, the "intron"-containing nucleic acids are expressed without further modification. In another embodiment, the nucleic acids are modified using the techniques described herein and exemplified *infra*, or as described in the references cited above, such as Sambrook *et. al.*, to produce a protein having an amino acid sequence of a native *Polistinae* venom enzyme (though, as discussed below, such a protein may have a different secondary or tertiary structure, or include other polypeptide sequences fused to it).

The nucleotide sequence coding for a *Polistinae* venom enzyme, or an immunomodulatory fragment, derivative or analog thereof, can be inserted into an appropriate expression vector, *i.e.*, a vector which contains the necessary elements for the transcription and translation of the inserted protein-coding sequence. Such elements are termed herein a "promoter." Thus, the nucleic acid molecule encoding the *Polistinae* venom enzyme is operationally associated with the promoter. An expression vector also preferably includes a replication origin. The necessary transcriptional and translational signals can also be supplied by the native gene encoding a *Polistinae* venom enzyme and/or its flanking regions. Potential host-vector systems include but are not limited to mammalian cell systems infected with virus (*e.g.*, vaccinia virus, adenovirus, etc.); insect cell systems infected with virus (*e.g.*, baculovirus); microorganisms such as yeast containing yeast vectors; or bacteria transformed with bacteriophage, DNA, plasmid DNA, or cosmid DNA. The expression elements of vectors vary in their strengths and specificities. Depending on the host-vector system utilized, any one of a number of suitable transcription and translation elements may be used.

In an alternative embodiment, a recombinant *Polistinae* venom enzyme of the invention, or an immunomodulatory fragment, derivative or analog thereof, is expressed chromosomally, after integration of the *Polistinae* venom enzyme coding sequence by recombination. In this regard, any of a number of amplification systems may be used to achieve high levels of stable gene expression (*See*, Sambrook *et al.*, 1989, *supra*, at Section 16.28).

The cell into which the recombinant vector comprising the nucleic acid molecule encoding the *Polistinae* venom enzyme is cultured in an appropriate cell culture

medium under conditions that provide for expression of the *Polistinae* venom enzyme by the cell. The expressed *Polistinae* venom enzyme can then be recovered from the culture according to methods well known in the art. Such methods are described in detail, *infra*.

In a another embodiment, a *Polistinae* venom enzyme-fusion protein can be expressed. A *Polistinae* venom enzyme-fusion protein comprises at least a functionally active portion of a non-*Polistinae* venom enzyme protein joined via a peptide bond to at least an immunomodulatory portion of a *Polistinae* venom enzyme. The non-*Polistinae* venom enzyme sequences can be amino- or carboxyl-terminal to the *Polistinae* venom enzyme sequences. A recombinant DNA molecule encoding such a fusion protein comprises a sequence encoding at least a functionally active portion of a non-*Polistinae* venom enzyme joined in-frame to the coding sequence for a *Polistinae* venom enzyme. It may encode a cleavage site for a specific protease, *e.g.*, Factor Xa, preferably at the juncture of the two proteins.

In another specific embodiment, a fragment of the *Polistinae* venom enzyme is expressed as a free (non-fusion) protein.

In a specific embodiment, the *Polistinae* venom phospholipase, and immunomodulatory fragments thereof, are expressed with an additional sequence comprising about six histidine residues, *e.g.*, using the pQE12 vector (QIAGEN, Chatsworth, CA). The presence of the histidine makes possible the selective isolation of recombinant proteins on a Ni-chelation column.

In another embodiment, a periplasmic form of the fusion protein (containing a signal sequence) can be produced for export of the protein to the *Escherichia coli* periplasm. Export to the periplasm can promote proper folding of the expressed protein.

Any of the methods previously described in Patent No.5,593,877 for the insertion of DNA fragments into a vector may be used to construct expression vectors containing a gene consisting of appropriate transcriptional/translational control signals and the protein coding sequences. These methods may include *in vitro* recombinant DNA and synthetic techniques and *in vivo* recombinants (genetic recombination). Expression of nucleic acid sequence encoding a *Polistinae* venom enzyme, or an immunomodulatory fragment thereof, may be regulated by a second nucleic acid sequence so that the *Polistinae* venom enzyme protein or peptide is expressed in a host transformed with the recombinant DNA molecule. For example, expression of a *Polistinae* venom enzyme protein may be

controlled by any promoter/enhancer element known in the art, but these regulatory elements must be functional in the host selected for expression. Promoters which may be used to control *Polistinae* venom enzyme gene expression include, but are not limited to, the CMV immediate early promoter, the SV40 early promoter region (Benoist and Chambon, 1981, Nature 290:304-310), the promoter contained in the 3' long terminal repeat of Rous sarcoma virus (Yamamoto, et al., 1980, Cell 22:787-797), the herpes thymidine kinase promoter (Wagner et al., 1981, Proc. Natl. Acad. Sci. U.S.A. 78:1441-1445), the regulatory sequences of the metallothionein gene (Brinster et al., 1982, Nature 296:39-42); prokaryotic expression vectors such as the β-lactamase promoter (Villa-Kamaroff, et al., 1978, Proc. Natl. Acad. Sci. U.S.A. 75:3727-3731), or the tac promoter (DeBoer, et al., 1983, Proc. Natl. Acad. Sci. U.S.A. 80:21-25); see also "Useful proteins from recombinant bacteria" in Scientific American, 1980, 242:74-94; promoter elements from yeast or other fungi such as the Gal 4 promoter, the ADC (alcohol dehydrogenase) promoter, PGK (phosphoglycerol kinase) promoter, alkaline phosphatase promoter; and the animal transcriptional control regions, which exhibit tissue specificity and have been utilized in transgenic animals.

Once a particular recombinant DNA molecule is identified and isolated, several methods known in the art may be used to propagate it. Once a suitable host system and growth conditions are established, recombinant expression vectors can be propagated and prepared in quantity. As previously explained, the expression vectors which can be used include, but are not limited to, the following vectors or their derivatives: human or animal viruses such as vaccinia virus or adenovirus; insect viruses such as baculovirus; yeast vectors; bacteriophage vectors (*e.g.*, lambda), and plasmid and cosmid DNA vectors, to name but a few.

In addition, a host cell strain may be chosen which modulates the expression of the inserted sequences, or modifies and processes the gene product in the specific fashion desired. Different host cells have characteristic and specific mechanisms for the translational and post-translational processing and modification (*e.g.*, glycosylation, cleavage [*e.g.*, of signal sequence]) of proteins. Appropriate cell lines or host systems can be chosen to ensure the desired modification and processing of the foreign protein expressed. For example, expression in a bacterial system can be used to produce an nonglycosylated core protein product. However, the enzyme protein expressed in bacteria

may not be properly folded. Expression in yeast can produce a glycosylated product. Expression in insect cells can be used to increase the likelihood of "native" glycosylation and folding of a heterologous *Polistinae* venom enzyme. Furthermore, different vector/host expression systems may affect processing reactions, such as proteolytic cleavages, to a different extent. It is interesting to note that it has been observed that glycosylation and proper refolding are not essential for immunomodulatory activity of a *Polistinae* venom allergen since bacterial-produced allergen is active in a T cell proliferation assay.

Vectors are introduced into the desired host cells by methods known in the art, *e.g.*, transfection, electroporation, electrotransfer, microinjection, transduction, cell fusion, DEAE dextran, calcium phosphate precipitation, lipofection (lysosome fusion), use of a gene gun, or a DNA vector transporter (see, *e.g.*, Wu et al., 1992, J. Biol. Chem. 267:963-967; Wu and Wu, 1988, J. Biol. Chem. 263:14621-14624; Hartmut et al., Canadian Patent Application No. 2,012,311, filed March 15, 1990).

Preferred vectors, particularly for protein production *in vivo*, are viral vectors, such as lentiviruses, retroviruses, herpes viruses, adenoviruses, adeno-associated viruses, vaccinia viruses, baculoviruses, and other recombinant viruses with desirable cellular tropism. Thus, a vector encoding a *Polistinae* venom enzyme can be introduced *in vivo* or *ex vivo* using a viral vector or through direct introduction of DNA. Expression in targeted tissues can be effected by targeting the transgenic vector to specific cells, such as with a viral vector or a receptor ligand, or by using a tissue-specific promoter, or both. Targeted gene delivery is described in International Patent Publication WO 95/28494, published October 1995.

Viral vectors commonly used for *in vivo* or *ex vivo* targeting and expression procedures are DNA-based vectors and retroviral vectors. Methods for constructing and using viral vectors are known in the art (*see, e.g.*, Miller and Rosman, BioTechniques, 7:980-990, 1992). Preferably, the viral vectors are replication defective, that is, they are unable to replicate autonomously in the target cell. Preferably, the replication defective virus is a minimal virus, *i.e.*, it retains only the sequences of its genome which are necessary for encapsidating the genome to produce viral particles.

DNA viral vectors include an attenuated or defective DNA virus, such as but not limited to herpes simplex virus (HSV), papillomavirus, Epstein Barr virus (EBV),

adenovirus, adeno-associated virus (AAV), vaccinia virus, and the like. Examples of particular vectors include, but are not limited to, a defective herpes virus 1 (HSV1) vector (Kaplitt, *et al.*, Molec. Cell. Neurosci. 2:320-330, 1991; International Patent Publication No. WO 94/21807, published September 29, 1994; International Patent Publication No. WO 92/05263, published April 2, 1994); an attenuated adenovirus vector, such as the vector described by Stratford-Perricaudet, *et al.* (J. Clin. Invest. 90:626-630, 1992; see also La Salle, *et al.*, Science 259:988-990, 1993); and a defective adeno-associated virus vector (Samulski, *et al.*, J. Virol. 61:3096-3101, 1987; Samulski, *et al.*, J. Virol. 63:3822-3828, 1989; Lebkowski, *et al.*, Mol. Cell. Biol. 8:3988-3996, 1988).

Various companies produce viral vectors commercially, including but by no means limited to Avigen, Inc. (Alameda, CA; AAV vectors), Cell Genesys (Foster City, CA; retroviral, adenoviral, AAV vectors, and lentiviral vectors), Clontech (retroviral and baculoviral vectors), Genovo, Inc. (Sharon Hill, PA; adenoviral and AAV vectors), Genvec (adenoviral vectors), IntroGene (Leiden, Netherlands; adenoviral vectors), Molecular Medicine (retroviral, adenoviral, AAV, and herpes viral vectors), Norgen (adenoviral vectors), Oxford BioMedica (Oxford, United Kingdom; lentiviral vectors), and Transgene (Strasbourg, France; adenoviral, vaccinia, retroviral, and lentiviral vectors).

In another embodiment, the vector can be introduced *in vivo* by lipofection, as naked DNA, or with other transfection facilitating agents (peptides, polymers, etc.). Synthetic cationic lipids can be used to prepare liposomes for *in vivo* transfection of a gene encoding a marker (Felgner, et. al., Proc. Natl. Acad. Sci. U.S.A. 84:7413-7417, 1987; Felgner and Ringold, Science 337:387-388, 1989; see Mackey, *et al.*, Proc. Natl. Acad. Sci. U.S.A. 85:8027-8031, 1988; Ulmer, *et al.*, Science 259:1745-1748, 1993). Useful lipid compounds and compositions for transfer of nucleic acids are described in International Patent Publications WO95/18863 and WO96/17823, and in U.S. Patent No. 5,459,127. Lipids may be chemically coupled to other molecules for the purpose of targeting (see Mackey, *et al.*, *supra*). Targeted peptides, *e.g.*, hormones or neurotransmitters, and proteins such as antibodies, or non-peptide molecules could be coupled to liposomes chemically.

Other molecules are also useful for facilitating transfection of a nucleic acid *in vivo*, such as a cationic oligopeptide (*e.g.*, International Patent Publication WO95/21931), peptides derived from DNA binding proteins (*e.g.*, International Patent

Publication WO96/25508), or a cationic polymer (*e.g.*, International Patent Publication WO95/21931).

Alternatively, non-viral DNA vectors for gene therapy can be introduced into the desired host cells by methods known in the art, *e.g.*, electroporation, microinjection, cell fusion, DEAE dextran, calcium phosphate precipitation, use of a gene gun (ballistic transfection; see, *e.g.*, U.S. Pat. No. 5,204,253, U.S. Pat. No. 5,853,663, U.S. Pat. No. 5,885,795, and U.S. Pat. No. 5,702,384 and see Sanford, TIB-TECH, 6:299-302, 1988; Fynan *et al.*, Proc. Natl. Acad. Sci. U.S.A., 90:11478-11482, 1993; and Yang *et al.*, Proc. Natl. Acad. Sci. U.S.A., 87:1568-9572, 1990), or use of a DNA vector transporter (see, *e.g.*, Wu, *et al.*, J. Biol. Chem. 267:963-967, 1992; Wu and Wu, J. Biol. Chem. 263:14621-14624, 1988; Hartmut, *et al.*, Canadian Patent Application No. 2,012,311, filed March 15, 1990; Williams, *et al.*, Proc. Natl. Acad. Sci. USA 88:2726-2730, 1991). Receptor-mediated DNA delivery approaches can also be used (Curiel, *et al.*, Hum. Gene Ther. 3:147-154, 1992; Wu and Wu, J. Biol. Chem. 262:4429-4432, 1987). US Patent Nos. 5,580,859 and 5,589,466 disclose delivery of exogenous DNA sequences, free of transfection facilitating agents, in a mammal. Recently, a relatively low voltage, high efficiency *in vivo* DNA transfer technique, termed electrotransfer, has been described (Mir, *et al.*, C.P. Acad. Sci., 321:893, 1998; WO 99/01157; WO 99/01158; WO 99/01175).

Both cDNA and genomic sequences can be cloned and expressed.

It is further contemplated that the *Polistinae* venom enzymes of the present invention, or fragments, derivatives or analogs thereof, can be prepared synthetically, *e.g.*, by solid phase peptide synthesis.

Isolation and Purification

Once the recombinant *Polistinae* venom enzyme protein is identified, it may be isolated and purified by standard methods including chromatography (*e.g.*, ion exchange, affinity, and sizing column chromatography), centrifugation, differential solubility, or by any other standard technique for the purification of proteins.

In a particular embodiment, a *Polistinae* venom enzyme and fragments thereof can be engineered to include about six histidyl residues, which makes possible the selective isolation of the recombinant protein on a Ni-chelation column. In a preferred aspect, the proteins are further purified by reverse phase chromatography.

In another embodiment, in which recombinant *Polistinae* venom enzyme is expressed as a fusion protein, the non-*Polistinae* venom enzyme portion of the fusion protein can be targeted for affinity purification. For example, antibody specific for the non-*Polistinae* venom enzyme portion of the fusion protein can be immobilized on a solid support, *e.g.*, cyanogen bromide-activated Sepharose, and used to purify the fusion protein. In another embodiment, a binding partner of the non-*Polistinae* venom enzyme portion of the fusion protein, such as a receptor or ligand, can be immobilized and used to affinity purify the fusion protein.

In one embodiment, a *Polistinae* venom enzyme-fusion protein, preferably purified, is used without further modification, *i.e.*, without cleaving or otherwise removing the non-*Polistinae* venom enzyme-portion of the fusion protein. In a preferred embodiment, the *Polistinae* venom enzyme-fusion protein can be used therapeutically, *e.g.*, to modulate an immune response.

In a further embodiment, the purified fusion protein is treated to cleave the non-*Polistinae* venom enzyme protein or portion thereof from the *Polistinae* venom enzyme. For example, where the fusion protein has been prepared to include a protease sensitive cleavage site, the fusion protein can be treated with the protease to cleave the protease specific site and release *Polistinae* venom enzyme.

In a particular embodiment of the present invention, such recombinant *Polistinae* venom enzymes include but certainly are not limited to those containing, as a primary amino acid sequence, all or part of the amino acid sequence substantially as depicted in Figures 1 (SEQ ID NO: 2) or 4 (SEQ ID NO:4), as well as fragments and other derivatives, and analogs thereof.

Derivatives and Analogs of Polistinae Venom Enzymes

The invention further relates to derivatives and analogs of *Polistinae* venom enzymes. The production and use of derivatives and analogs related to *Polistinae* venom enzymes are within the scope of the present invention. The derivative or analog is immunomodulatory, *i.e.*, capable of modulating an antigen-specific immune response. Moreover, analogs or derivatives of *Polistinae* venom enzymes, particularly phospholipase and hyaluronidase from *Polistes annularis,* can also be used to treat immune system related diseases or disorders, or a symptom related thereto. In another embodiment, the derivative or analog can bind to a *Polistinae* venom enzyme-specific immunoglobulin, including IgG

and IgE. Derivatives or analogs of *Polistinae* venom enzyme can be tested for the desired immunomodulatory activity by procedures known in the art, including but not limited to the assays described *infra*.

In particular, *Polistinae* venom enzyme derivatives can be made by altering the nucleic acid sequences of the invention by substitutions, additions or deletions. Due to the degeneracy of nucleotide coding sequences, other DNA sequences which encode substantially the same amino acid sequence as a nucleic acid encoding a *Polistinae* venom enzyme may be used in the practice of the present invention. These include but are not limited to nucleotide sequences comprising all or portions of a gene encoding the *Polistinae* venom enzyme that are altered by the substitution of different codons that encode the same amino acid residue within the sequence, thus producing a silent change. Likewise, the derivatives of the invention include, but are not limited to, those containing, as a primary amino acid sequence, all or part of the amino acid sequence of a *Polistinae* venom enzyme, including altered sequences in which functionally equivalent amino acid residues are substituted for residues within the sequence resulting in a conservative amino acid substitution. For example, one or more amino acid residues within the sequence can be substituted by another amino acid of a similar polarity which acts as a functional equivalent, resulting in a silent alteration. Substitutes for an amino acid within the sequence may be selected from other members of the class to which the amino acid belongs. For example, the nonpolar (hydrophobic) amino acids include alanine, leucine, isoleucine, valine, proline, phenylalanine, tryptophan and methionine. The polar neutral amino acids include glycine, serine, threonine, cysteine, tyrosine, asparagine, and glutamine. The positively charged (basic) amino acids include arginine, lysine and histidine. The negatively charged (acidic) amino acids include aspartic acid and glutamic acid.

Derivatives or analogs of *Polistinae* venom enzyme include but are not limited to those which are substantially homologous to a *Polistinae* venom enzyme or fragments thereof, or whose encoding nucleic acid is capable of hybridizing to a nucleic acid molecule encoding a *Polistinae* venom enzyme. Hybridization can occur under moderately stringent to highly stringent conditions, depending on the degree of sequence similarity, as is well known in the art.

The derivatives and analogs of the invention can be produced by various methods known in the art. The manipulations which result in their production can occur at

the gene or protein level. For example, the nucleic acid sequence of the cloned *Polistinae* venom enzyme can be modified by any of numerous strategies known in the art (Maniatis, T., 1990, Molecular Cloning, A Laboratory Manual, 2d ed., Cold Spring Harbor Laboratory, Cold Spring Harbor, New York). The sequence can be cleaved at appropriate sites with restriction endonuclease(s), followed by further enzymatic modification if desired, isolated, and ligated *in vitro*. In the production of the gene encoding a derivative or analog of a *Polistinae* venom enzyme, care should be taken to ensure that the modified gene remains within the same translational reading frame as *Polistinae* venom enzyme, uninterrupted by translational stop signals.

Additionally, the gene encoding a *Polistinae* venom enzyme can be mutated *in vitro* or *in vivo*, to create and/or destroy translation, initiation, and/or termination sequences, or to create variations in coding regions and/or form new restriction endonuclease sites or destroy preexisting ones, to facilitate further *in vitro* modification. Any technique for mutagenesis known in the art can be used, including but not limited to, *in vitro* site-directed mutagenesis (Hutchinson, C., et al., 1978, J. Biol. Chem. 253:6551; Zoller and Smith, 1984, DNA 3:479-488; Oliphant et al., 1986, Gene 44:177; Hutchinson et al., 1986, Proc. Natl. Acad. Sci. U.S.A. 83:710), use of TAB® linkers (Pharmacia), etc. PCR techniques are preferred for site directed mutagenesis (see Higuchi, 1989, "Using PCR to Engineer DNA", in *PCR Technology: Principles and Applications for DNA Amplification*, H. Erlich, ed., Stockton Press, Chapter 6, pp. 61-70).

Manipulations of the recombinant *Polistinae* venom enzyme may also be made at the protein level. Included within the scope of the invention are recombinant *Polistinae* venom enzyme fragments or other derivatives or analogs which are differentially modified during or after translation, *e.g.*, by glycosylation, acetylation, phosphorylation, amidation, reduction and carboxymethylation, derivatization by known protecting/blocking groups, proteolytic cleavage, linkage to an antibody molecule or other cellular ligand, etc. Any of numerous chemical modifications may be carried out by known techniques, including but not limited to specific chemical cleavage by cyanogen bromide, trypsin, chymotrypsin, papain, V8 protease, $NaBH_4$; acetylation, formylation, oxidation, reduction; metabolic synthesis in the presence of tunicamycin; etc.

In a particular embodiment, the *Polistinae* venom enzyme or immunomodulatory fragment thereof is expressed in an insect cell expression system, *e.g.*,

using a baculovirus expression vector. As pointed out above, this should yield "native" glycosylation and structure, particularly secondary and tertiary structure, of the expressed polypeptide. Native glycosylation and structure of the expressed polypeptide may be very important for diagnostic uses, since the enzyme specific antibodies detected in diagnostic assays will be specific for the native enzyme, *i.e.*, as introduced by a sting from a vespid.

Activity Assays With Peptides of the Invention

Numerous assays are known in immunology for evaluating the immunomodulatory activity of an antigen. For example, the *Polistinae* venom enzyme proteins produced by expression of the nucleic acid molecules of the invention can be used in diagnostic assays for allergic diseases, which are described in detail, *infra*. In general, such proteins can be tested for the ability to bind to antibodies specific for the enzyme. Preferably, such antibodies that are detected in the diagnostic assay are of the IgE class. However, it is important to note that natural allergen-specific antibodies have been found to bind weakly to denatured vespid venom allergens. *Polistinae* venom enzymes produced in eukaryotic expression systems, and particularly insect cell expression systems, may have the correct structure for antibody binding. *Polistinae* venom enzymes expressed in bacterial expression systems may not, and would thus require refolding prior to use in a diagnostic assay for antibody binding.

In another embodiment, the proteins of the invention can be tested in a proliferation assay for T cell responses. For such T cell response assays, the expression system used to produce the enzyme does not appear to affect the immunomodulatory activity of the protein. Generally, lymphocytes from a sensitized host are obtained. The host can be a mouse that has been immunized with a *Polistinae* venom enzyme, such as a *Polistinae* venom phospholipase or hyaluronidase that has been produced recombinantly according to the present invention.

In a preferred embodiment, peripheral blood leukocytes are obtained from a human who is sensitive to vespid venom. Using techniques that are well known in the art, T lymphocyte response to the protein can be measured *in vitro*. In a specific embodiment, *infra*, T cell responses are detected by measuring incorporation of ^{3}H-thymidine, which increases with DNA synthesis associated with proliferation.

Cell proliferation can also be detected using an MTT assay (Mossman, 1983, J. Immunol. Methods 65:55-63; Niks and Otto, 1990, J. Immunol. Methods 130:140-151).

Any method for detecting T cell proliferation known in the art can be used with the *Polistinae* enzyme produced according to the present invention.

Similarly, lymphokine production assays can be practiced according to the present invention. In one embodiment, lymphokine production can be assayed using immunological or co-stimulation assays (see, *e.g.*, Fehlner et al., 1991, J. Immunol. 146:799) or using the ELISPOT technique (Czerkinsky, et al., 1988, J. Immunol. Methods 110:29). Alternatively, mRNA for lymphokines can be detected, *e.g.*, by amplification (see Brenner, et al., 1989, Biotechniques 7:1096) or *in situ* hybridization (see, *e.g.*, Kasaian and Biron, 1989, J. Immunol. 142:1287). Of particular interest are those individuals whose T cells produce lymphokines associated with IgE isotype switch events, *e.g.*, IL-4 and IL-5 (Purkeson and Isakson, 1992, J. Exp. Med. 175:973-982). Also of interest are the polypeptide fragments of the *Polistinae* venom enzyme that contain epitopes recognized by T cells involved in IgE switch events.

Thus, in a preferred aspect, the proteins produced according to the present invention can be used in *in vitro* assays with peripheral blood lymphocytes or, more preferably, cell lines derived from peripheral blood lymphocytes, obtained from vespid venom enzyme sensitive individuals to detect secretion of lymphokines ordinarily associated with allergic responses, *e.g.*, IL-4. Such assays may indicate which venom component or components are responsible for the allergic condition. More importantly, the fragments of the *Polistinae* venom enzyme can be tested. In this way, specific epitopes responsible for T cell responses associated with allergic response can be identified. The sequences of such epitopes can be compared to other vespid venom enzymes and to environmental or autologous proteins to determine if there are sequence similarities that suggest possible cross-reactivity. The peptides can be tested for the ability to induce T cell anergy, *e.g.*, by mega-dose administration, modification to produce an epitope antagonist, administration in the absence of the appropriate costimulatory signals, and other methods thought to result in T cell anergy. Peptides containing such epitopes are ideal candidates for therapeutics.

In a further embodiment, the polypeptides of the invention can be used directly in assays to detect the extent of cross-reactivity with other environmental proteins and/or homologous proteins, with which they share sequence similarity. In particular, the fragments of the *Polistinae* venom enzymes that have sequence similarity with such environmental, and more particularly, homologous proteins can be evaluated for cross

reactivity with antibodies or T cell specific for such proteins. In a specific embodiment, the cross reactivity of *Polistinae* venom phospholipases with human lipases can be evaluated. In another specific embodiment, the cross reactivity of *Polistinae* venom hyaluronidase with the sperm membrane protein PH-20 is evaluated.

Diagnostic and Therapeutic Uses of the Polistinae Venom Enzyme Polypeptides

The present invention provides a plentiful source of a pure *Polistinae* venom enzyme, or fragments, derivatives or analogs thereof, produced by recombinant techniques. Alternatively, given the sequence information provided by the present invention, polypeptide fragments, derivatives or analogs of the *Polistinae* venom enzymes can advantageously be produced by peptide synthesis.

The invention contemplates use of *Polistinae* venom enzymes, or immunomodulatory fragments, derivatives or analogs thereof for the preparation of diagnostic or therapeutic compositions, for the use in the diagnosis and therapy of vespid venom allergen-specific allergic conditions, treating vespid venom allergen-specific allergic conditions, treating immune system related conditions, and modulating immune response in a mammal against an immunogen. In particular, Polistes phospholipase, more particularly *Pol a* phospholipase A_1, or Polistes hyaluronidase, in particular *Pol a* hyaluronidase, or immunomodulatory fragments, derivatives or analogs of phospholipase or hyaluronidase, are contemplated for use in diagnosis, therapy, treatment, and modulation of immune response according to the present invention.

Diagnostic Methods

As use herein, the term diagnostic includes *in vitro* and *in vivo* diagnostic assays. Generally, such assays are designed to measure the activity of IgE antibodies specific for a given allergen. Such diagnostic assays depend heavily on the availability of pure allergen. This is especially true for determining sensitivity to a specific allergen component of a vespid venom. *In vitro* diagnostic assays for enzyme sensitivity include radioimmunoassay (RIA), immunoradiometric immunoassay (IRMA), radio-allergosorbent tests (RAST), enzyme-linked immunosorbent assay (ELISA), ELISPOT, magnetic allergosorbent assay, immunoblots, histamine release assays, and the like.

In a further embodiment, the present invention provides for determining the presence of epitopes that are predominantly reactive with IgE antibodies, or with other

isotypes, *e.g.*, IgG. Such epitopes may overlap or be distinct. In particular, fragments of the *Polistinae* venom enzymes of the invention can be used to identify such specific B cell epitopes. Identification of specific epitopes can provide a basis for developing therapies, as described *infra*.

The present invention contemplates *in vitro* diagnostic assays on peripheral blood lymphocytes, as described *supra*. Such diagnostic assays can give detailed information about the enzyme-specific T cell responses, the phenotype of the T cell response, and preferably the T cell epitope of the enzyme involved in T cell responses. The immunodominant epitope and the epitope involved in IgE isotype class switch events can be detected, if they are not the same. In particular, the T cell epitopes of *Polistinae* venom enzymes that stimulate proliferation and/or lymphokine secretion of T cells of a phenotype associated with IgE isotype class switching events can be identified for a specific individual, or for a class of individuals who share MHC haplotype or a predominant T cell receptor variable region expression, or both.

In vivo assays for allergenicity generally consist of skin prick sensitivity assays, in which serially diluted amounts of an allergen are administered either subcutaneously or intradermally into a patient's skin, and wheel and erythema reactions are detected. As with *in vitro* assays, the availability of pure venom enzyme greatly increases the value of the results of the *in vivo* diagnostic assays since cross-reactivity with impurities in extracts prepared from vespid venom sacs can be avoided.

Therapeutic Methods

Therapeutic compositions of the invention (see, *infra*) can be used in immunotherapy, also referred to as hyposensitization therapy. Immunotherapy has proven effective in allergic diseases, particular insect allergy. Allergens are administered parenterally over a long period of time in gradually increasing doses. Such therapy may be particularly effective when the allergen or allergens to which the patient is sensitive have been specifically identified and the therapy is targeted to those allergen(s). Thus, the availability of pure *Polistinae* venom enzyme in large quantities is important for immunotherapy of allergy.

In another embodiment, the present invention contemplates use of polypeptides comprising at least an immunomodulatory T cell epitope of a *Polistinae* venom enzyme to induce specific T cell allergy to a vespid venom enzyme. Identification of such

peptides is described *supra*. More preferably, a peptide comprising such a T cell epitope and lacking a B cell epitope can be administered to a patient. The presence of B cell epitopes on an allergen can cause an undesirable systemic reaction when the allergen is used for immunotherapy. Thus, a particular advantage of the invention is the capability to provide allergen polypeptides that do not cause undesirable systemic effects.

In one embodiment, one or more polypeptide fragments can be injected subcutaneously to decrease the T cell response to the entire molecule, *e.g.*, as described by Brine et al. (1993, Proc. Natl. Acad. Sci. U.S.A. 90:7608-12).

In another embodiment, one or more polypeptide fragments can be administered intranasally to suppress allergen-specific responses in naive and sensitized subjects (see *e.g.*, Hoyne et al., 1993, J. Exp. Med. 178:1783-88).

Administration of a *Polistinae* venom enzyme peptide of the invention is expected to induce anergy, resulting in cessation of allergen-specific antibody production or allergen-specific T cell response, or both, and thus, have a therapeutic effect.

In a preferred aspect of the invention, peptide based therapy to induce T cell anergy is customized for each individual or a group of individuals. Using the diagnostic methods of the present invention, the specific T cell epitope or epitopes of a vespid venom enzyme involved in the allergic response can be identified. Peptides comprising these epitopes can then be used in an individualized immunotherapy regimen.

Treatment of Immune System Related Diseases or Disorders, or a Symptom Related Thereto

As explained above, the present invention relates to polypeptides for treating immune system related diseases or disorders, or for modulating immune response in a mammal towards an immunogen, wherein the polypeptides are encoded by isolated nucleic acid molecules which encode *Polistinae* venom enzymes, such phospholipase A_1 and hyaluronidase from *Polistes annularis*, to name only a few. In particular, components of vespid venom, particularly phospholipase and hyaluronidase, have applications in modulating a subject's immune response to various immunogens, such as pathogens and viruses, to name only a few. In a particular embodiment, components of a *Polistinae* venom, and particularly phospholipase A_1 and hyaluronidase from *Polistes annularis* and conserved variants thereof, fragments thereof, or analogs or derivatives thereof modulate a subject's immune system to have increased ability to combat pathogens and viruses

including, but not limited to, HIV, Herpes Simplex virus, or papilloma virus. In a specific embodiment, such a method comprises administering to a subject a therapeutically effective amount of a pharmaceutical composition comprising a polypeptide encoded by an isolated nucleic acid molecule comprising a DNA sequence of SEQ ID NOs: 1 or 3, degenerate variants thereof, fragments thereof, or analogs or derivatives thereof, or an isolated nucleic acid molecule hybridizable thereto, wherein the polypeptide comprises an antigenic portion of a B cell epitope or an immunomodulatory portion of a T cell epitope of *Polistes annularis* phospholipase A_1 or hyaluronidase.

Furthermore, it has been discovered that components of *Polistinae* venom, such as phospholipase A_1 and hyaluronidase of *Polistes annularis*, to name only a few, also have applications in treating an immune system related disease or disorder, or a symptom related thereto. As used herein, the phrase "immune system related disease or disorder" refers to a disease or disorder which evokes an immune response in a subject, or effects the ability of the immune system to respond to an immunogen. Examples of immune system related diseases or disorders which can be treated with agents and pharmaceutical compositions of the invention include, but are not limited to, a pathogenic disease or disorder; a viral disease or disorder, e.g. HIV, Herpes Simplex virus, or papilloma virus; or an autoimmune disease, e.g. arthritis or Lupus. Hence, the present invention encompasses agents for treating an immune system related disease or disorder, or a symptom related thereto, in a specific embodiment comprising an isolated polypeptide encoded by an isolated nucleic acid molecule comprising a DNA sequence of SEQ ID NOS:1 or 3, degenerate variants thereof, fragments thereof or analogs or derivatives thereof, wherein the isolated polypeptide comprises an immunomodulatory portion of a T cell epitope or an antigenic portion of a B cell epitope of *Polistes annularis* phospholipase A_1 or hyaluronidase.

Hence, naturally, the present invention extends to pharmaceutical compositions for treating an immune system related disease or disorder, comprising a *Polistinae* venom enzyme, degenerate variants thereof, fragments thereof., or analogs or derivatives thereof. Moreover, the present invention extends to a method for treating an immune system related disease or disorder, or a symptom related thereto, comprising administering a therapeutically effective amount of a pharmaceutical composition for treating an immune system related disease or disorder to a subject. The phrase

"therapeutically effective amount" is used herein to mean an amount sufficient to treat, and preferably increase by at least about 30 percent, more preferably by at least 50 percent, most preferably by at least 90 percent, the ability of the immune system of a subject to combat effectively an immunogen. As further studies are conducted, information will emerge regarding appropriate dosage levels for modulation of immune system response towards an immunogen in various patients, and the ordinary skilled worker, considering the therapeutic context, age and general health of the recipient, will be able to ascertain proper dosing. Delivery can be of the protein or a gene therapy vector. Hence, for example, should the immune system related disease or disorder involve HIV, a clinically significant change would, for example, involve an increase in white blood cell count in a subject to whom a pharmaceutical composition of the invention is administered relative to white blood cell count prior to administration. Other such examples of monitoring a clinically significant change in a subject will be readily apparent to one of ordinary skill in the art. Furthermore, as further studies are conducted, information will emerge regarding appropriate dosage levels for treating an immune system related disease or disorder, or a symptom related thereto in various patients, and the ordinary skilled worker, considering the therapeutic context, age and general health of the recipient, will be able to ascertain proper dosing. Examples of pharmaceutically acceptable compositions are described *infra*.

Pharmaceutically Acceptable Compositions

The *in vivo* diagnostic or therapeutic compositions of the invention may also contain appropriate pharmaceutically acceptable carriers, excipients, diluents and adjuvants. As used herein, the phrase "pharmaceutically acceptable" preferably means approved by a regulatory agency of a government, in particular the Federal government or a state government, or listed in the U.S. Pharmacopeia or another generally recognized pharmacopeia for use in animals, and more particularly in humans. Suitable pharmaceutical carriers are described in "Remington's Pharmaceutical Sciences" by E.W. Martin.

Such pharmaceutically acceptable carriers can be sterile liquids, such as water and oils, including those of petroleum, animal, vegetable or synthetic origin, such as peanut oil, soybean oil, mineral oil, sesame oil and the like. Water is a preferred carrier when the pharmaceutical composition is administered intravenously. Saline solutions and aqueous dextrose and glycerol solutions can also be employed as liquid carriers,

particularly for injectable solutions. Suitable pharmaceutical excipients include mannitol, human serum albumin (HSA), starch, glucose, lactose, sucrose, gelatin, malt, rice, flour, chalk, silica gel, magnesium carbonate, magnesium stearate, sodium stearate, glycerol monostearate, talc, sodium chloride, dried skim milk, glycerol, propylene, glycol, water, ethanol and the like. These compositions can take the form of solutions, suspensions, tablets, pills, capsules, powders, sustained-release formulations and the like.

Such compositions will contain an effective diagnostic or therapeutic amount of the active compound together with a suitable amount of carrier so as to provide the form for proper administration to the patient. While intravenous injection is a very effective form of administration, other modes can be employed, such as by injection, or by oral, nasal or parenteral administration.

The invention will be further clarified by the following examples, which are intended to be purely exemplary of the invention.

EXAMPLE 1: PAPER WASP PHOSPHOLIPASE

Based, in part, on the methods and disclosure of U.S. Patent No. 5,593,877, nucleic acids encoding *Pol a* (paper wasp) phospholipase were obtained. However, these nucleic acids surprisingly include internal sequences that do not code for an amino acid sequence found as expected on the native protein. Although the nucleic acids described in this Example are cDNAs, and are not genomic, they appear to include "introns".

MATERIALS AND METHODS

The methods used are the same as those described in U.S. Patent No. 5,593,877 using RACE.

Results

When examining paper wasp phospholipase A_1 cDNA produced with RACE, it was observed that its length was longer than necessary to encode paper wasp phospholipase A_1 protein. It was discovered that, surprisingly, this augmented length was the result introns incorporated into the paper wasp phospholipase A_1 cDNA. Such a discovery was unexpected in light of studies conducted on the cDNAs of other vespid venoms, which invariably do not contain any introns. For example, the phospholipase cDNAs of yellowjacket and hornet contain no such introns.

Because of this major unforeseen difference between paper wasp phospholipase A_1 cDNA and other vespid venom phospholipase cDNAs, special biotechniques and steps were required to isolate paper wasp phospholipase A_1 cDNA, which were not needed to obtain the venom phospholipase cDNA from other vespids, such as hornet and yellowjacket. In particular, in order to isolate the cDNA sequence encoding phospholipase A_1 for paper wasp, it was necessary to determine the size and location and number of introns.

Using the amino acid sequence derived from the cyanogen bromide degradation of paper wasp phospholipase A_1, the genetic code, and the nucleotide sequence of wasp phospholipase cDNA derived from the RACE protocol, two introns were discovered. The first intron, hereinafter referred to as "*papla intron 1*" comprises a nucleotide sequence as set forth in SEQ ID NO:5 (Figure 2A). *Papla intron 1* comprises 114 nucleotides, and is normally located between nucleotides 111 and 112 of the cDNA sequence encoding phospholipase A_1, set forth In SEQ ID NO:1.

A second intron, hereinafter referred to as "*papla intron 2*" was also discovered. This intron comprises a nucleotide sequence as set forth in SEQ ID NO:6 (Figure 2B). *Papla intron 2* contains 127 nucleotides, and is normally located between nucleotides 720 and 721 of SEQ ID NO:1.

In order to isolate the cDNA sequence encoding paper wasp phospholipase A_1 (SEQ ID NO:1), these introns had to be removed from the paper wasp phospholipase A_1 cDNA derived from RACE without disturbing the reading frame of the coding nucleotides. In essence, paper wasp phospholipase A_1 cDNA had to be re-designed so that only encoding nucleotides would be included. This re-design process was technically very difficult because, should one encoding nucleotide be accidentally removed along with an intron, or should one non-coding nucleotide not be removed, a reading frame shift would be produced which would result in mutations and could cause premature termination of the expression of the cDNA.

In this re-design process, specially designed oligonucleotides were chemically synthesized, each complementary to coding nucleotides located 5' and 3' of one of the introns. The amplified paper wasp phospholipase A_1 cDNA derived from RACE was then cloned into a self-replicating plasmid. This plasmid was denatured, and, under low stringency conditions, the oligonucleotides were permitted to anneal to the paper wasp

phospholipase A_1 cDNA, leaving the introns single stranded. These oligonucleotides then served as primers for DNA synthesis, which generated a double stranded plasmid wherein the introns were deleted from one of the strands. A cell was then transfected with the plasmid using methods described above, and the cell was then cloned. Since one of the two DNA strands in the original plasmid had the introns deleted, half of the transfected cells contained a double stranded plasmid in which the introns had been removed. The cloned were then screened to isolate the cells having the plasmid comprising paper wasp cDNA comprising a DNA sequence of SEQ ID NO:9 (without introns). Copies of the particular plasmid were then isolated and sequenced to confirm the deletion of the introns. The re-designed paper wasp phospholipase A_1 cDNA was then removed from the particular plasmid, sequenced, amplified, and cloned into an expression vector, using the procedures described in Example 1 and in Application Serial No. 08/474,853 and in U.S. Patent 5,593,877, which are hereby incorporated by reference in their entireties.

A comparison of the deduced amino acid sequence of paper wasp phospholipase A_1 (SEQ ID NO:2) with other vespid venom phospholipases was performed. In particular, SEQ ID NO:2 was compared with phospholipase from white face hornet (*D. maculata*) (SEQ ID NO:7) and phospholipase from yellow jacket (*V. vulgaris*) (SEQ ID NO:8). The results of this sequence comparison are shown in Figure 3.

EXAMPLE 2: PAPER WASP HYALURONIDASE

Using the procedures described in U.S. Patent No. 5,593,877, the cDNA sequence encoding paper wasp (*Pol a*) hyaluronidase (SEQ ID NO:3) and its corresponding amino acid sequence (SEQ ID NO:4) were isolated and are set forth in Figure 4. Nucleotides 449 through 536 of SEQ ID NO:3 encode a portion of a signal sequence. Hence, the amino acid residue at the N terminus of mature *Pol a* hyaluronidase is serine, which is encoded by nucleotides 536, 537, and 538.

Surprisingly, paper wasp hyaluronidase cDNA produced from the RACE protocol set forth above had greater length than necessary to encode *Pol a* hyaluronidase protein. Hence, it was concluded paper wasp hyaluronidase cDNA contained at least one intron. The presence of the at least one intron within the wasp hyaluronidase cDNA was unexpected in light of studies on hyaluronidase cDNA from other vespid venoms, such as yellowjacket and hornet, which do not contain introns. As a result, special biotechniques

similar to those employed to isolate paper wasp phospholipase A_1 cDNA, and set forth in Example 3 *supra*, were required to isolate the cDNA encoding sequence of paper wasp hyaluronidase.

Initially, a determination was made as to the location and size of the introns within the paper wasp hyaluronidase cDNA. Once the introns were located, they had to be removed in such a manner as not to disturb any coding nucleotides. Hence, just as with paper wasp phospholipase A_1 cDNA, it was necessary to re-design paper wasp hyaluronidase cDNA so that only encoding nucleotides would be included. This re-design process was technically very difficult because, should one encoding nucleotide be accidentally removed along with an intron, or should one non-coding nucleotide not be removed, a missense frameshift mutation would be placed into the wasp hyaluronidase cDNA.

The cDNA encoding mature paper wasp hyaluronidase (SEQ ID NO:3) was prepared using procedure similar to that used to isolate the cDNA encoding paper wasp phospholipase A_1 *supra*, The cDNA without introns was then sequenced, amplified, and cloned into an expression vector, again using the procedures described above.

Paper wasp hyaluronidase cDNA was found to contain one intron. This intron, hereinafter referred to as "*pahya*", is 94 nucleotides long, and has a nucleotide sequence as set forth in SEQ ID NO:9 (Figure 5). Normally, this intron is located between nucleotides 733 and 734 of SEQ ID NO:3.

A comparison of the amino acid sequence of paper wasp hyaluronidase (SEQ ID NO:4) with other vespid venom phospholipases was performed. In particular, SEQ ID NO:4 was compared with hyaluronidase from bee venom (SEQ ID NO:10), hyaluronidase from white face hornet (*D. maculata*) (SEQ ID NO:11) and hyaluronidase from yellowjacket (*V. vulgaris*) (SEQ ID NO:12). The results of this sequence comparison are shown in Figure 15.

* * *

The present invention is not to be limited in scope by the specific embodiments described herein since such embodiments are intended as but single illustrations of one aspect of the invention and any microorganisms which are functionally

equivalent are within the scope of this invention. Indeed, various modifications of the invention in addition to those shown and described herein will become apparent to those skilled in the art from the foregoing description and accompanying drawings. Such modifications are intended to fall within the scope of the appended claims.

It is also to be understood that all base pair sizes given for nucleotides and molecular weights for all biomolecules are approximate and are used for the purpose of description.

Various patents, references, procedures, and other documents are cited herein, the disclosures of which are incorporated by reference herein in their entirety.